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(54) **A method and apparatus for automatic attachment of a finishing block to a lens**

(57) A method and apparatus for automatic determination of a location and orientation of a finishing block to be attached to a lens. The lens has either visible reference features or invisible reference features associated with a prescribed or predetermined value of at least one optical characteristic of the lens, with respect to which reference features the location and orientation of the finishing block are in a predetermined geometric relationship. The apparatus comprises a support (3) for carrying the lens (A); a reference features finder (5) for obtaining a graphic image of the lens (A) if the reference features are distinguishable when imaged, and/or obtaining a mapping image of the lens (A) based on which the optical characteristic of the lens (A) may be calculated, if the reference features are non-distinguishable when imaged, and a computer (24) for processing the graphic and/or mapping image of the lens (A), to derive therefrom the coordinates of the reference features and to determine the location and orientation of the finishing block (1) based on their predetermined geometrical relationship with the reference features and using the coordinates of the reference features.

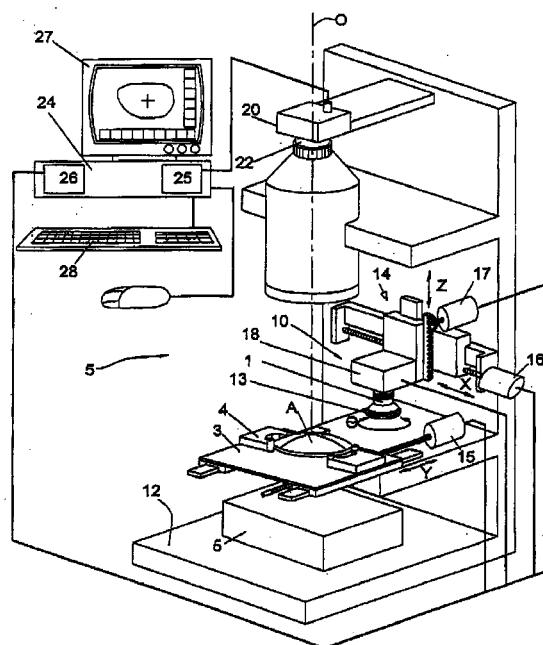


FIG. 1

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Description**FIELD OF THE INVENTION**

[0001] This invention relates to a method and apparatus for automatic attachment of a finishing block to a lens, such as an ophthalmic lens.

BACKGROUND OF THE INVENTION

[0002] It is known in lens production that a lens that has been properly cut, ground, polished and coated, proceeds to a finishing operation of edging where the periphery of the lens is cut in an edging device, to conform a frame in which it is to be held. To properly position the lens within the edging device, a finishing block is attached to the lens at a location and orientation defined by reference features on the lens, which is used for the fixation of the lens within the edging device, keeping the lens orientation as required.

[0003] In the past, finishing blocks were attached to lenses manually. However, even for experienced and highly skilled lens makers, it was often difficult to manually attach the block to the lens in proper registration with the reference features.

[0004] An apparatus for ophthalmic lens blocking is known in the art, wherein an operator observing through a view port first positions the lens within the apparatus by manual aligning the reference features on the lens with an alignment pattern in the apparatus and, once the lens is properly positioned, the finishing block is attached to the lens at a location defined relative to the reference features.

[0005] Clearly, visual comparing the reference features on a lens with the alignment pattern in the apparatus and accurate manual positioning of the lens is a time consuming process, which requires an experienced operator for proper lens alignment. As any manual process, it may suffer from lens positioning inaccuracies, which may subsequently cause incorrect use of spectacles. This is particularly critical for spectacles with progressive and bifocal ophthalmic lenses. Also, the necessity of visual comparison of the reference features on a lens with the alignment pattern makes the known apparatus non-suitable for use with lenses where the reference features are invisible.

SUMMARY OF THE INVENTION

[0006] In accordance with one aspect of the present invention, there is provided a method for automatically determining a location and orientation of a finishing block to be attached to a lens having either visible reference features or invisible reference features associated with a predetermined or prescribed value of at least one optical characteristic of the lens, with respect to which reference features said location and orientation are in a predetermined geometric relationship. The method

comprises the following steps:

(a) obtaining a graphic image of said lens if the reference features are distinguishable when imaged, or obtaining a mapping image of the lens based on which said optical characteristic of the lens may be calculated, if the reference features are non-distinguishable when imaged;

(b) computer processing said graphic and/or said mapping image to derive therefrom the coordinates of the reference features; and

(c) determining said location and orientation of the finishing block based on their said predetermined geometric relationship with respect to said reference features, using said coordinates of the reference features.

[0007] Thus, in accordance with the method of the present invention, graphic images and optical characteristics of lenses are analyzed by a computer for finding the position of their reference features and for automatically attaching a finishing block to a lens in such a location and orientation relative to the reference features, as prescribed by the lens manufacturer or predetermined otherwise.

[0008] In the simplest case, the reference features may be in the form of pre-printed marks indicating the location and orientation at which the finishing block is to be attached. For example, for a single vision lens, such marks may be in the optical center of the lens and along its cylinder axis. Similarly, the finishing block mark may be in the optical center of a bifocal lens with the orientation of the finishing block being defined relative to the position of the bifocal segment of the lens. In a progressive lens, the finishing block mark is known to be in the form of a printed fitting cross.

[0009] Alternatively, the reference features may be in the form of other marks or areas distinguishable when imaged, that are specific for different kinds of lenses and with respect to which the location and orientation of the finishing block is prescribed. For example, in a bifocal lens, such a specific area is its bifocal segment, and in a progressive lens, hidden marks can be used.

[0010] If, however, a lens to which the finishing block is to be attached, has no printed or other reference features that may be graphically imaged, mapping of at least one optical characteristic of the lens may be performed to derive the reference features therefrom, provided that the location and orientation of the finishing block relative to these signs have been prescribed. For example, for a single vision lens, optical power mapping enables determination of the optical center of the lens where its prism power value is zero and of the orientation of the cylinder axis passing therethrough. In a single vision lens with spherical, cylindrical and prescribed prism powers, the reference features may be a location where the prism power has a prescribed value and where the cylinder and prism axes have a prescribed

mutual angular orientation. In a progressive lens which has no printed reference features, spherical and cylinder power maps may be obtained, whereby its optical center may be determined and the precise positions of the far and near vision points may be established according to the prescribed values and prescribed far and near inter-pupillary distances. All this will constitute the reference features of the progressive lens, based on which the location and orientation of the finishing block to be attached to the lens can be calculated, in accordance with an original prescription.

[0011] According to another aspect of the present invention, there is provided an apparatus for automatically determining a location and orientation of a finishing block to be attached to a lens having either visible reference features or invisible reference features associated with at least one optical characteristic of the lens, with respect to which reference features said location and orientation are in a predetermined geometric relationship. The apparatus comprises:

- a support for carrying the lens;
- a reference features finder for obtaining a graphic image of said lens if the reference features are distinguishable when imaged, and/or obtaining a mapping image based on which said optical characteristic of the lens may be calculated, if the reference features are non-distinguishable when imaged, and
- a computer for processing the graphic and/or mapping image of the lens, to derive therefrom the coordinates of the reference features and to determine said location and orientation of the finishing block based on their said predetermined geometrical relationship with the reference features and using said coordinates of the reference features.

[0012] The reference features finder may comprise one or both of the imaging and mapping branches. In the latter case, these branches may be arranged in one common set-up to graphically image or map the lens along one optical axis in either imaging or mapping mode of the apparatus, or rather these branches may be in the form of two separate imaging and mapping stations of the apparatus.

[0013] The imaging branch of the reference features finder may be any appropriate optics capable of providing graphic images in which printed or hidden reference features of a processed lens are clearly distinguishable. Such optics may be based on dark field or bright field lens illumination or it may be in the form of shadow imaging optics.

[0014] The mapping branch of the reference features finder may be any optics capable of mapping at least one of the following optical characteristics of a lens: spherical power, cylindrical power, cylinder axis, prism power, prism axis, coma, and any local lens characteristic. Maps obtained by such optics may also pro-

vide information regarding geometrical lens layout, bifocal segment layout, location of far and near vision points, etc.

[0015] It should be noted that the use of imaging and mapping of lenses is well known for the purposes of optical shop testing. However, to the best of the inventor's knowledge, none of the known techniques has ever been used for automatic determination of the location and orientation of a finishing block for its automatic attachment to the lens, based on the automatic determination of visible or invisible reference features on the lenses.

[0016] In view of the above, it is clear that the method and apparatus of the present invention cannot only serve for the automatic attachment of a finishing block to a lens but also may provide conventional mapping and lensmeter functions, with the possibility of printing out lenses' graphic images and optical maps. The method and apparatus of the present invention may also be used for determining geometrical centers of lenses, finding lens edges and automatic lens-to-frame fitting

[0017] The apparatus of the present invention may be compact and portable and it can be placed on a table, workbench or other support and operated by a user while sitting. The user does not need to be particularly experienced.

[0018] The present invention is particularly useful for automated orienting and attaching a finishing block to a lens, the periphery of which needs to be cut and finished in an edging device. It should be understood, however that the invention is in no way limited to this particular application and can also be used to attach a holder or a surface block to a lens blank that is to be ground and polished.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of an apparatus for automatic attachment of a finishing block to a lens, according to the present invention;

Fig. 2 is a schematic illustration of an apparatus for automatic attachment of a finishing block to a lens, according to one particular embodiment of the present invention;

Figs. 3, 4 and 5 are graphic images of lenses obtained by an apparatus of the kind shown in Fig. 2;

Fig. 6 is a schematic illustration of an apparatus for automatic attachment of a finishing block to a lens, according to another particular embodiment of the present invention;

Figs. 7 and 8 are mapping images of lenses obtained by an apparatus of the kind shown in Fig. 6;

Figs. 9, 10 and 11 are optical power maps of lenses obtained by an apparatus of the kind shown in Fig. 6;

Fig. 12 is a schematic illustration of an apparatus for automatic attachment of a finishing block to a lens, according to a further particular embodiment of the present invention;

Fig. 13A is a schematic illustration of a blocking unit of the apparatus shown in Fig. 1;

Fig. 13B is a schematic illustration of an alternative embodiment of the blocking unit shown in Fig. 13A;

Figs. 14A and 14B are schematic illustrations of a finishing block manipulator of the blocking unit shown in Fig. 13A, and

Figs. 15A and 15B are schematic illustrations of an apparatus for automatic attachment of a finishing block to a lens, according to a still further particular embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Fig. 1 schematically shows an apparatus for determining a location and orientation of a finishing block 1 to be attached to a lens A, and for the attachment of the finishing block 1 to the lens A, which lens has either visible reference features or invisible reference features associated with a predetermined or prescribed value of at least one optical characteristic of the lens A. The location and orientation at which the finishing block 1 should be attached to the lens A are in a prescribed or otherwise predetermined geometrical relationship with the reference features.

[0021] As seen in Fig. 1, the apparatus has an optical axis O and it generally comprises

- a lens support plate 3 with a clamping device 4 for clamping the lens A, the lens support plate being movable in Y direction so as to bring the lens A into at least two working positions, of which one is an imaging position at the optical axis O of the apparatus and the other one is a non-imaging position remote from the optical axis O;
- a reference features finder designated generally as 5, for processing the lens A in its obtaining a graphic image of the lens A if the reference features are distinguishable when imaged and/or by obtaining a mapping image of the lens based on which the above-mentioned optical characteristic of the lens may be calculated, if the reference features are non-distinguishable when imaged and
- a blocking unit 10 with the finishing block in the form of a plastic or metallic block with an adhesive pad 13 detachably attached to its end, and a finishing block displacement mechanism generally designated as 14 capable of moving the blocking unit 10

in X, Z and θ directions to bring the finishing block to the lens A at its non-imaging position, at a location and orientation that are prescribed relative to the reference features of the lens A.

[0022] The apparatus shown in Fig. 1 also comprises a main frame 12 carrying the above components of the apparatus and it may have a housing to accommodate the apparatus therein.

[0023] To enable the movement of the lens support plate 3 in the Y-direction, it is provided with a driving motor 15 with a linear actuator. The finishing block displacement mechanism 14 comprises driving motors 16 and 17 with linear actuators and a driving motor 18 with a rotating actuator for respective linear and rotational displacement of the blocking unit 10.

[0024] The reference features finder 5 of the apparatus shown in Fig. 1 includes one of or both a lens imaging optics and a lens mapping optics, whose components, which are not shown specifically in Fig. 1, are located along the optical axis O of the apparatus on one or two sides of the lens support plate 3. The reference features finder further includes an image acquisition device 20 to capture images from the lens imaging optics and/or lens mapping optics.

[0025] The lens imaging optics may be any system capable of providing a high quality graphic image of a lens with the reference features in the form of printed or hidden marks. For example, it may be optics with dark field or bright field lens illumination or it may be a shadow imaging optics.

[0026] The lens mapping optics may be any optics capable of providing a map of either of spherical power cylindrical power, cylinder axis, prism power, prism axis, coma, or any local lens characteristic, from which the reference features may be derived. Such reference features may be coordinates of the optical center of a lens, orientation of its cylinder axis, coordinates of far and near vision points, etc. The lens mapping optics may be built in the form of shearing interferometer, moiré interferometer (see e.g. Takasaki, H, "Moiré Topography," *Appl. Opt.*, **9**, 1467 (1970); *Appl. Opt.*, **12**, 845 (1973)), Shack - Hartmann test optical setup (see e.g. Shack R.B. & B.C. Platt Production and Use of a Lenticular Hartmann Screen", *J. Opt. Soc. Am.*, **61**, 656 (1971)), or rather in the form of optical setup disclosed in co-pending Israel Patent Application No. 130465 for Grid Analysis Measuring & Mapping (GAMMA) method.

[0027] The image acquisition device 20 is equipped with an imaging camera lens 22 that may be a CCD, TV or still camera, CID or CMOS camera, having an optical axis coinciding with the optical axis O of the apparatus, for projecting an image of the processed lens A obtained by the lens imaging optics and/or lens mapping optics on a light-detecting element of the imaging camera (CCD, CID or CMOS chip). The camera lens 22 is preferably built in the form of a telecentric or tele-scopic type camera lens with a high depth of focus pro-

viding the imaging of the front surface of the lens A in practically parallel rays. However, other types of camera lenses may be used.

[0028] The apparatus shown in Fig. 1 further comprises a computer 24 with a frame grabber 25 via which it is connected to the output of the image acquisition device 20, I/O board 26, a display 27 and keyboard 28 through which the user may input in the computer identification and prescribed information regarding the lens A to be processed and selectively control various functions of the apparatus. The computer 24 has appropriate software for:

- controlling the overall performance of the apparatus;
- processing graphic and mapping images obtained from the lens imaging and lens mapping optics for determining exact coordinates of the reference features of the lens A as well as its form, dimensions, orientation and any other needed information concerning the lens;
- determining, based on the pre-determined geometrical relationship with respect to the reference features and using the coordinates of the reference features, coordinates of the location and orientation at which the finishing block 1 is to be attached to the lens A; and
- manipulating the support plate 3 and the blocking unit 10 to attach the finishing block 1 to the lens A at the location and orientation thereof determined by the computer.

[0029] When the apparatus is designed for lens-to-frame fitting, the computer 24 is preferably provided with an interface enabling its receiving data from a frame tracer device, to further process both the lens graphic or mapping image and the data from the frame tracer, to enable automatic frame fitting into lens patterns in any prescribed manner.

[0030] Figs. 2, 6 and 12 illustrate different embodiments of the apparatus generally illustrated in Fig. 1, where particular designs of reference features under are used for processing lenses having different kinds of the reference features.

[0031] In the apparatus shown in Fig. 2 the reference features finder 5 includes a lens imaging optics (not designated) and it is intended to process lenses in which the reference features has a geometrically distinguishable form. Thus, the reference features may be in the form of printed marks indicating the location and orientation at which the finishing block 1 should be attached to the lens A. Alternatively, the reference features may be in the form of other printed marks, or hidden marks in progressive lenses, or bifocal segment in bifocal lenses, relative to which the location and orientation at which the finishing block 1 is to be attached to the lens is prescribed or predetermined otherwise.

[0032] In the apparatus shown in Fig. 2, the lens

imaging optics is in the form of a self-compensating imaging shadowgraphy optical setup as described in EP 0 856 728, incorporated herein by reference. The lens imaging optics has an illumination means in the form of a point source of radiation 31 providing suitable preferably wide divergence of radiation illuminating the lens A along the optical axis O. It is desirable that the point source of radiation 31 has minimal possible dimensions, whereby high resolution of measurements may be obtained. For example, the point source 31 may be in the form of a diode laser 32 with a focusing optics 33 and pinhole 34. The lens imaging optics further comprises a beam-deflecting element 36, a collimating lens 38 and a projecting screen 40. The beam-deflecting element 36 may be in the form of an ordinary beam-splitter. The projecting screen 40 may be in the form of a diffusing or luminescent or phosphorescent surface or any kind of back-scattering surface. The camera lens 22 is in optical coincidence with the radiation source 31, i.e. they are optically equidistant from the optical element A.

[0033] When the lens imaging optics is operated, the collimating lens 38 collimates the radiation beam from the radiation source 31 and, in cooperation with the camera lens 22, provides the imaging of the lens A in parallel rays. The processed lens A illuminated by the collimated incident radiation forms on the projecting screen 40 a shadow pattern. Distribution of brightness in the shadow pattern depends on the optical power of the lens A and on local power and transparency deviations produced by the reference features of the lens. Since the camera lens 22 is in the optical coincidence with the point source of radiation 31, the rays forming the image of the lens A propagate along the same optical path as the incident rays illuminating the lens A. As a result, relative dimensions of the reference features and their disposition relative to the edges of the lens A remain undistorted in the image of the shadow pattern obtained by the image acquisition device 20, i.e. they are exactly the same as in the lens surface. This enables the computer 24 to calculate the coordinates of the reference features 24 and to subsequently determine the location and orientation at which the finishing block 1 is to be attached to the lens A. Examples of images of the shadow patterns from a bifocal lens and from a progressive lens with printed and hidden marks on their surfaces are shown on Figs. 3, 4 and 5 respectively.

[0034] Fig. 6 illustrates another embodiment of the apparatus of the present invention where the reference features finder 5 includes a lens mapping optics (not designated) for measuring and mapping optical power of lenses, and it is intended to process lenses in which the reference features are not geometrically distinguishable when imaged such as explained above with reference to Fig. 2. In such lenses and depending on their type, the reference features which may be coordinates of the optical center of a lens, orientation of its cylinder axis, coordinates of far and near vision points, etc, are to be derived from the mapping images or optical power

maps, based on which the location and orientation are to be determined, at which the finishing block 1 should be attached to the lens.

[0035] In the apparatus shown in Fig. 6, the lens mapping optics comprises a diffusive light source 52 stationary mounted on the main frame 12, and a contrast mapping pattern 54 on a pattern supporting plate 56. The diffusive light source 52 may be of any type capable of giving a relatively uniform illumination of the processed lens A from below, and it is preferably in the form of back light illuminating LED matrix with a diffusive element. The mapping pattern 54 may be printed or engraved on a substrate made of a transparent or translucent material such as mineral glass, milky glass, ground glass or paper. The pattern may be in the form of number of regularly ordered points, lines or circles of known dimensions and at known mutual dispositions, concentric circular pattern with radial lines, staggered arranged squares, regular grid with highlighted origin lines or the like.

[0036] The mapping pattern 54 with its supporting plate 56 are moveably mounted on a slider 58 with a linear actuator 59 driven by a motor 60, providing their movement up and down along the axis Z. This enables the apparatus to process lenses in a wide range of optical powers, so that the higher the power of a lens, the less the distance thereto from the mapping pattern 54.

[0037] In the apparatus shown in Fig. 6, the camera lens 22 has a narrow, preferably pin-hole, entrance pupil (not shown).

[0038] When the lens mapping optics of the apparatus shown in Fig. 6 is operated, the radiation from the illuminator 52 illuminating the pattern 54 and being scattered thereby, passes through the lens A towards the camera lens 22. Though each point of the pattern 54 is illuminated by a wide range of light rays from the diffusive illuminator 52, only those that are focused at the entrance pupil of the camera lens 22 will pass there-through to the image acquisition device 20, producing thereby an image of each point of at least a portion of the pattern and, consequently, an optical power map of the lens A. Ray tracing in this case is mathematically equivalent to the ray tracing of the Shack-Hartmann method known to those skilled in the art, and the mathematics developed for this method may be applied to method of power measurement providing results similar to those of the Shack - Hartmann method. Examples of mapping images recorded by a CCD camera in testing of ophthalmic lenses using lens mapping optics of the kind described above are shown in Figs. 7 and 8. These Figures represent images of a pattern, which is a regular squared grid recorded through a bifocal lens with the base spherical and cylindrical power and a segment additional power (Fig. 7) and recorded through a progressive lens (Fig. 8).

[0039] The computer 24 is provided in the apparatus shown in Fig. 6, with a dedicated software to process the mapping pattern image obtained as described

above, to identify the pattern control points and/or lines and to compare their measured coordinates and/or form with those of a pattern image produced without the lens A and stored in the computer's memory. The measured deformation of the pattern image caused by the lens A enables the calculation therefrom of the lens's refractive properties. Spherical power results in the magnification of the pattern and cylinder power results in its deformation with the direction of the deformation indicating the orientation of the cylinder axis. Prismatic power results in parallel displacement of points of the pattern image relatively to their position stored in the computer memory. Direction of the displacement indicates the prism axis orientation. Prismatic power is to be calculated by means of the following formula:

$$Z=100 \cdot \frac{r-R}{B}$$

where r and R are radial coordinates of a ray impinging the lens A and the pattern 54 respectively, B is a distance between the lens A and the pattern.

[0040] For more accurate lens power measuring and mapping, images of the mapping pattern are to be taken in two different positions thereof, and their analysis is to be performed by the comparison of the measured coordinates of the control points of the two pattern images with those of the corresponding pattern images obtained without the lens A and stored in the computer memory. Thereby, there may be calculated coordinates of any reference points on the processed lens A having prescribed optical characteristics, e.g. prescribed local power, as well as the mutual orientation of its local cylinder and prism axes, and consequently, the location and orientation at which the finishing block 1 should be attached to the lens A.

[0041] The output of the apparatus working in the lens power mapping mode may be presented in the form of topographical spherical and cylindrical power maps, as shown in Figs. 9 to 11. Figs. 9 and 10 show respective spherical and cylindrical power maps of an ophthalmic progressive lens, and Fig. 11 shows a prism power map of a single vision lens. More details of the lens mapping optics of the above kind may be found in the counterpart Israeli application No. 130465 incorporated herein by reference.

[0042] Fig. 12 illustrates an apparatus according to a further particular embodiment of the present invention, where the reference features finder includes both the lens imaging branch as in the embodiment of Fig. 2 and the lens mapping branch as in the embodiment of Fig. 6. The lens imaging branch allows the determination of exact geometrical position of the lens A and its reference features that are in the form of printed or hidden marks if the lens A is a progressive lens, bifocal segment if the lens A is a bifocal lens, and a geometrical center if the lens A is a single vision lens. It also enable

the determination of the shape and dimensions of the lens A. The lens mapping branch allows for determining optical features of the lens such as spherical, cylindrical and prism power at every point of the lens, cylinder and prism axis directions and exact coordinates of the optical center of the lens, which all may constitute the lens's reference features. The combination of the lens graphical imaging and lens mapping branches in one apparatus as shown in Fig. 12 enables the determination of the reference features and, consequently, of the coordinates of the location and orientation at which the finishing block 1 should be attached to the lens A, for all possible lens types.

[0043] In the apparatus of the Fig. 12 the optical components of the reference features finder 5 that are located above the lens A are basically as in the embodiment of Fig. 2, and those located below the lens A are basically as in the embodiment of Fig. 6 with the difference that in addition to the mapping pattern 54 disposed below the lens A, the apparatus includes a diffusing or back scattering screen 70 having a non-working position 70' remote from the optical axis O and a working position 70" on the optical axis O above the mapping pattern 54. To this end, the screen 70 is mounted on a slider 72 driven by a motor 74 enabling the displacement of the screen 70 in the Y-direction.

[0044] With reference to Figs. 13A, 13B, 14A and 14B, there will be described in more details the blocking unit 10 carrying the finishing block 1, and mechanisms providing relative displacement between the blocking unit 10 and the lens support plate 3, used in the embodiments of the apparatus of the present invention, described above.

[0045] Fig. 13A shows the lens support plate 3 movably mounted on sliders 76 whose linear actuator 78 is driven by the motor 15, providing the movement of the lens support plate 3 along the axis Y. Fig. 13A further shows the finishing block displacement mechanism 14 comprising a slider 80 carrying the blocking unit 10 and connected with a linear actuator 82 driven by the motor 17, to provide the movement of the blocking unit 10 along the axis Z. The finishing block displacement mechanism 14 also comprises a slider 84 carrying the slider 80 with its linear actuator 82 and the motor 17, and connected with a linear actuator 86 driven by the motor 16 to provide the movement of the finishing block 10 along the axis X. The finishing block displacement mechanism 14 further comprises the motor 18 accommodated within the blocking unit 10 and having a shaft (not seen) on which the finishing block 1 is detachably attached by a spring coupling 87, to provide the rotational movement of the finishing block 1 in the θ -direction around the axis Z.

[0046] As seen in Fig. 14A and 14B, the blocking unit 10 is further provided with a finishing block manipulator 88 enabling the rotation of the blocking unit 10 between its vertical working position in which the pad 13 faces downwardly towards the lens A to which the finishing block 1 is to be attached, and a non-working upper position in which the pad 13 faces the operator, thereby enabling the finishing block manual loading in a position convenient to the operator. To this end, the manipulator 88 includes an axle 90 on which the blocking unit 10 is fixedly mounted, a roll 92 attached to the blocking unit 10 and a wedge 94 mounted on the slide 84 or stationary fixed on the apparatus main frame (not seen in Figs. 14A and 14B). Such a construction provides for the rotation of the finishing block manipulator 88 for 80° - 100° around the axle 90 upon the slide 80 moving along the axis Z, and fixation of the manipulator 88 in the upper position as it is shown on Fig. 14B. This non-working position should normally be the blocking unit's starting position when it is loaded with the finishing block and it should also be taken by the blocking unit 10 after the finishing block has been attached to the lens A.

[0047] It should be mentioned regarding the displacement mechanisms that they may have any appropriate design different from that described above with reference to Figs. 13A, 14A and 14B, providing the relative linear and rotational displacement between the lens support plate 3 and the finishing block 1. For example, as shown in Fig. 13B, the lens support plate 3 may be built in the form of an X-Y table 100 provided with linear actuators and motors enabling its displacement in X and Y directions, and with the mechanism enabling the rotation of the lens A in θ direction. In this case, the blocking unit 10 may be displaceable only in Z direction. Also, both the lens support plate and the finishing block may have only linear displacement mechanisms, whilst the provision of their relative rotational displacement may be avoided by means of the registration of the lens's orientation and subsequent use of the registered data when a finishing operation is performed on the lens.

[0048] Also, the actuators and the motors used in providing the above displacements may be of any suitable kind. For example, the actuators 82, 86 and 96 may be built in the form of a timing belt, a rack-and-pinion, a screw-and-nut actuator, or the like. The motors 15, 16, 17 and 18 may be of any appropriate kind but, preferably, the motors 15, 16 and 18 responsible for the displacements in X, Y and θ directions are stepped or servo motors, and the motor 17 is a DC motor.

[0049] The motors 15, 16, 17 and 18 are all connected to the computer 24 via the interface board 26 and they are controlled by the computer to perform the above described displacements in their due time.

[0050] In operation, an initial state of the apparatus, according to the embodiments described with reference to Figs. 1, 2, 6 and 12 has the lens support plate 3 and the blocking unit 10 in their non-working positions. The non-working position of the lens support plate 3 is with its lens clamping device 4 open, and the non-working position of the blocking unit 10 is away from the optical axis O of the apparatus. For processing the lens A, the operator manually loads the finishing block 1 with the

adhesive pad 13 into the blocking unit 10 and places the lens A on the support plate 3, where it is fixed by the lens clamping device 4. The finishing block 1 has a horizontal reference line (not seen in the drawings) it is loaded by the operator so that the reference line is oriented in a pre-determined manner. The operator further inputs into the computer 24, via the keyboard 28, all necessary information about the lens to be processed. If the lens is to be edged, the information regarding the frame in which it is to be mounted is also to be introduced in the computer. This can be accomplished by providing the computer, for example, with a job number corresponding to a particular lens and particular frame shape. The computer 24 correlates the specified job number with the data regarding the frame stored in memory or gets the relevant information from a frame tracer or any other external source. The computer memory is also loaded with the information regarding the location and orientation at which the finishing block is to be attached to the lens, relative to the reference features on the lens. The operator initiates the apparatus via the keyboard 28. The support plate 3 moves the lens A into its imaging position where its geometrical center is located in the proximity of the optical axis O of the apparatus. Then the reference features finder 5 processes the lens A by graphically imaging the lens A if it is of the kind that its reference features are distinguishable when imaged, or by obtaining a mapping image of the lens A, if it is of the kind that its reference features are non-distinguishable when imaged. The graphic image of the lens and/or its mapping image are transferred via the frame grabber 25 to the computer 24 which analyzes them according to the dedicated program to determine the reference features and the edges of the lens A, to compare the dimensions of the lens and the position of its reference features with the shape, dimensions and the central point position of the frame to fit the processed lens to the frame. The computer further uses this information to calculate the location at which the finishing block 1 has to be attached to the processed lens A and the angular orientation of the finishing block 1.

[0051] The location of the finishing block and its orientation relative to the reference features of the lens depend on the type of the lens A to which it is to be attached, and the manner of their determination depends on the kind of the reference features that the lens has, as follows:

- for a single vision lens in which reference features are in the form of three marked points indicating the optical center of the lens and the orientation of its cylinder axis, the location of the finishing block will preferably be at the central point of the lens with the finishing block's horizontal reference line being parallel to a line passing through the marked points or at a prescribed angle thereto; in this case, the apparatus should preferably be used with the reference features finder in the form of the lens imaging

optics as in Figs. 2 and 12;

- for a single vision lens in which no reference signs are marked, the finishing block should be located at the optical center which is determined by the apparatus in which the reference features finder is in the form of the lens mapping optics as in Figs. 6 and 12 at a location on the lens where the prism power has zero value or at a point having a prescribed disposition relative to the optical center, and with the orientation of the finishing block's horizontal reference line along the cylinder axis or at a prescribed angle thereto;
- for a single vision lens without marked reference features and with prescribed spherical, cylindrical and prism powers and prescribed angle between the cylinder and prism axes, the apparatus should be used in which the reference features finder is in the form of the lens mapping optics as in Figs. 6 and 12, for determining a location with the prism power of a prescribed value and with a prescribed angle between the cylinder and prism axes, with respect to which the location and orientation of the finishing block is subsequently calculated in accordance with a prescription of lens manufacture;
- for a bifocal lens where the bifocal segment is preferably used as the reference features, the apparatus should preferably be used with the reference features finder in the form of the lens imaging optics as in Figs. 2 and 12, to determine the exact position and orientation of the bifocal segment, with respect to which the location and orientation of the finishing block are subsequently calculated in accordance with a prescription of lens manufacture;
- for a progressive lens in which the reference features are in the form of printed fitting cross and central line, the apparatus should preferably be used with the reference features finder in the form of the lens imaging optics as in Figs. 2 and 12, and the location of the finishing block will be on the fitting cross with the horizontal reference line of the finishing block being parallel to the lens central line;
- for a progressive lens which has no printed reference features, hidden marks may be used as reference features, and the apparatus should preferably be used with the reference features finder in the form of the lens imaging optics as in Figs. 2 and 12, for determining the lens orientation by finding the precise positions of the hidden marks, with respect to which the location and orientation of the finishing block is subsequently calculated in accordance with a prescription of lens manufacture
- for a progressive lens which has no printed or hidden reference features, the apparatus should be used in which the reference features finder is in the form of the lens mapping optics as in Figs. 6 and 12, for determining the optical center of the lens based on its spherical and cylinder power maps, determining the lens orientation by finding the pre-

cise positions of its far and near vision points according to their prescribed values and prescribed far and near interpupillary distances, with respect to which the location and orientation of the finishing block is subsequently calculated in accordance with a prescription of lens manufacture.

[0052] Figs. 15A and 15B illustrate a further embodiment of an apparatus according to the present invention, for processing pairs of lenses and their frame fitting. In this embodiment, the reference features finder 5 may be of any design described above or any other appropriate design.

[0053] The apparatus has a lens support plate 110 and a blocking unit 111. The support plate 110 is movable along axis X and the blocking unit 111 is moveable in Y and Z directions. The lens support plate 110 has two independent clamping devices 112 and 114, which are capable of clamping both lenses A1 and A2 and spectacle frames F1 and F2.

[0054] Processing spectacle frames F1 and F2 results in accurate frame shape and interpupillary distance measurements and processing lenses A1 and A2 results in the attachment thereto of the finishing blocks at locations and orientations determined *inter alia* based on the measurements of the frames.

[0055] The configuration of the apparatus as shown in Figs. 15A and 15B, enables processing of lens pairs and spectacle frames in the manner described above with reference to Figs. 2, 6 and 12 and thereby enables lens-to-frame fitting without additional information regarding the frames.

[0056] The method and apparatus according to the present invention and, particularly, their optical setups and their displacement mechanisms may have features different from those in the examples described above, within the scope of the claims.

Claims

1. A method for automatic determination of a location and orientation of a finishing block to be attached to a lens having either visible reference features or invisible reference features associated with a prescribed or predetermined value of at least one optical characteristic of the lens, with respect to which reference features said location and orientation are in a predetermined geometric relationship, comprising the steps of:

(a) obtaining a graphic image of said lens if the reference features are distinguishable when imaged, or obtaining a mapping image of said lens based on which said optical characteristic of the lens may be calculated, if the reference features are non-distinguishable when imaged; (b) computer processing the graphic or mapping image to derive therefrom the coordinates

of the reference features; and

(c) determining said location and orientation of the finishing block based on their said predetermined geometric relationship with respect to said reference features, using said coordinates of the reference features.

2. A method according to Claim 1, wherein said predetermined geometrical relationship is of a kind prescribed by a lens manufacturer.

3. A method according to Claim 1, wherein said reference features are in the form of preprinted marks indicating said location and orientation at which the finishing block is to be attached to the lens.

4. A method according to Claim 1, wherein said reference features are in the form of marks or areas on the lens different from the location at which the finishing block is to be attached.

5. A method according to Claim 1, wherein said reference features are invisible when viewed but distinguishable when graphically imaged as specified in step (a).

6. A method according to Claim 1, wherein said reference features are invisible when viewed and non-distinguishable when graphically imaged as specified in step (a).

7. A method according to Claim 3, 4, 5 or 6, wherein said lens is single vision lens.

8. A method according to Claim 4, wherein said lens is a bifocal lens.

9. A method according to Claim 3, 4, 5 or 6, wherein said lens is a progressive lens.

10. A method of automatic attachment of a finishing block to a lens including the automatic determination of a location and orientation of the finishing block according to any one of Claims 1 to 9.

11. A method according to Claim 10, wherein before said attachment of the finishing block to the lens, the block and the lens are provided with computer-controlled relative linear and rotational displacements with respect to each other.

12. A method according to Claim 10, wherein before said attachment of the finishing block to the lens, the block and the lens are provided with computer-controlled relative linear displacements with respect to each other, and the lens's orientation is registered by a computer for the registered data to be subsequently used in a finishing operation per-

formed on the lens.

- 13.** An apparatus for automatic determination of a location and orientation of a finishing block to be attached to a lens having either visible reference features or invisible reference features associated with a prescribed or predetermined value of at least one optical characteristic of the lens, with respect to which reference features said location and orientation are in a predetermined geometric relationship, comprising:

- a support for carrying the lens;
- a reference features finder for obtaining a graphic image of said lens if the reference features are distinguishable when imaged, and/or obtaining a mapping image of the lens based on which said optical characteristic of the lens may be calculated, if the reference features are non-distinguishable when imaged, and
- a computer for processing the graphic and/or mapping image of the lens, to derive therefrom the coordinates of the reference features and to determine said location and orientation of the finishing block based on their said predetermined geometrical relationship with the reference features and using said coordinates of the reference features.

- 14.** An apparatus according to Claim 13, wherein said reference features finder comprises an imaging optics for obtaining said graphic image or a mapping optics for obtaining said mapping image.

- 15.** An apparatus according to Claim 13, wherein said reference features finder comprises an imaging optics and a mapping optics, which are arranged in one common set-up to alternatively graphically image or map the lens along one optical axis in either imaging or mapping mode of the apparatus.

- 16.** An apparatus according to Claim 13, wherein said reference features finder comprises an imaging optics and a mapping optics in the form of two separate imaging and mapping stations of the apparatus.

- 17.** An apparatus according to Claim 16, wherein said stations has each its own optical axis and said support for carrying the lens is movable between said stations to bring said lens into the optical axis of each of them.

- 18.** An apparatus according to Claim 16, wherein the apparatus has one optical axis and said stations are movable into a working position at said optical axis of the apparatus.

- 19.** An apparatus according to Claim 14, 15 or 16, wherein said imaging optics is a shadow imaging optics.

- 20.** An apparatus according to Claim 14, 15 or 16, wherein said mapping optics is capable of mapping at least one of the following optical characteristics of a lens: spherical power, cylindrical power, cylinder axis, prism power, prism axis, coma, and any local lens characteristic.

- 21.** An apparatus according to Claim 13, capable of automated orienting and attaching a finishing block to a lens the periphery of which needs to be cut and finished in an edging device.

- 22.** An apparatus according to Claim 21, capable of determining geometrical centers of lenses, finding lens edges and automatic lens-to-frame fitting.

- 23.** An apparatus according to Claim 22, further having an interface for receiving data from a frame tracer device, or any other external source, to be used in said automatic lens-to-frame fitting.

- 24.** An apparatus according to Claim 14, capable of visually presenting graphic images and maps of lenses processed thereby.

- 25.** An apparatus for the automatic attachment of a finishing block to a lens including the apparatus for determining a location and orientation at which the finishing block is to be attached according to any one of Claims 13 to 24, and further including a blocking unit for carrying said finishing block in a predetermined original orientation and for computer-controlled manipulating the finishing block for attaching it to the lens at said location and orientation.

- 26.** An apparatus according to Claim 25, further comprising mechanisms for computer-controlled relative linear and rotational displacements of the finishing block and the lens with respect to each other.

- 27.** An apparatus according to Claim 25, further comprising mechanisms for computer-controlled relative linear displacements with respect to each other, said computer being adapted for the registration of the lens's orientation, for the registered data to be subsequently used in a finishing operation performed on the lens.

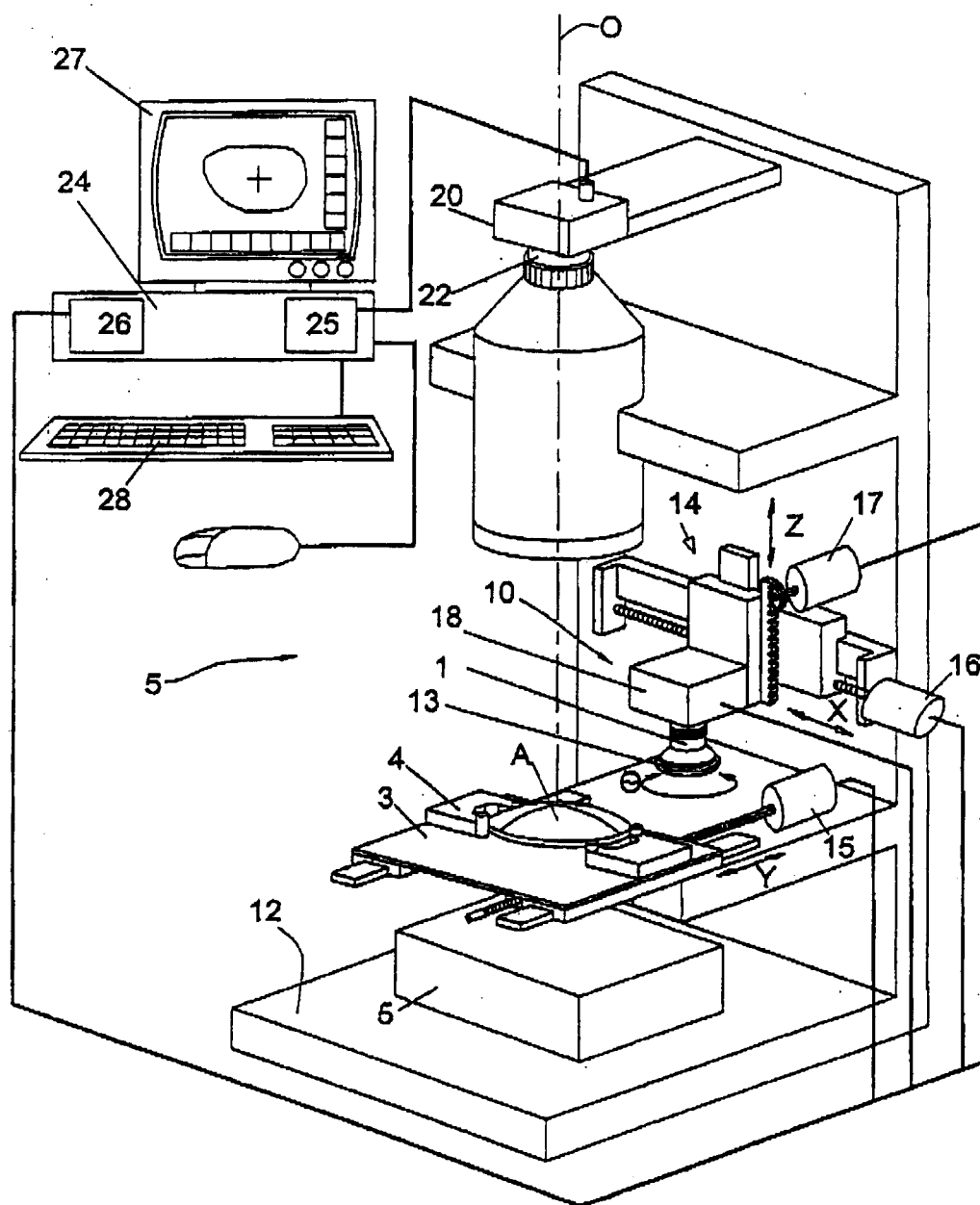


FIG. 1

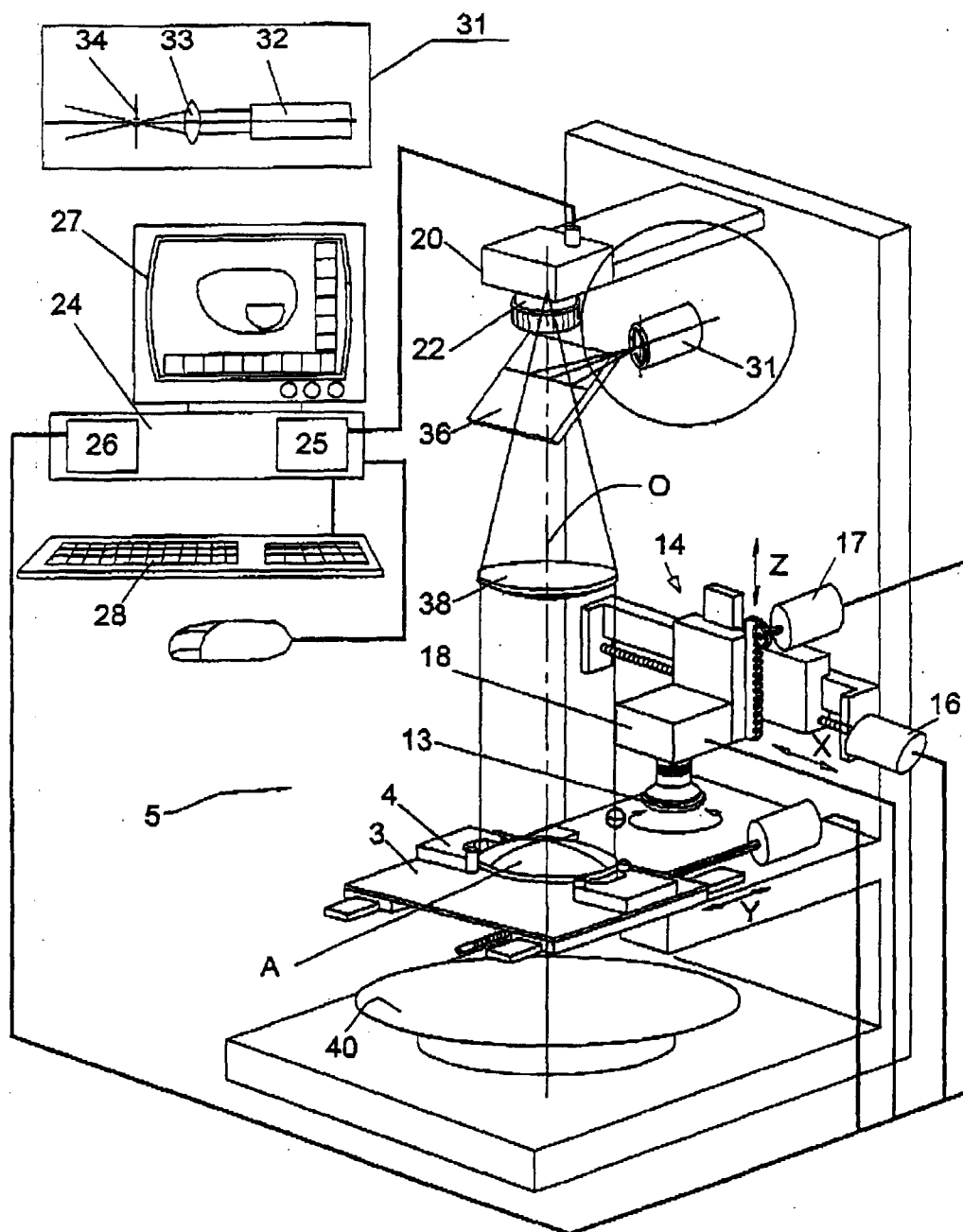


FIG. 2

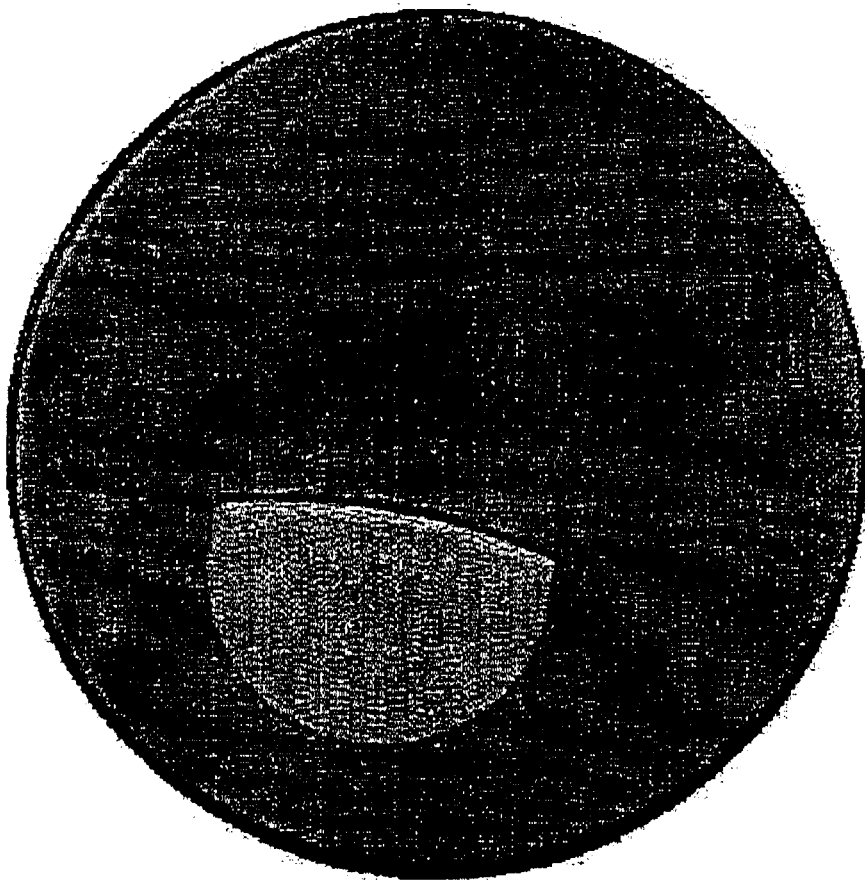


FIG. 3

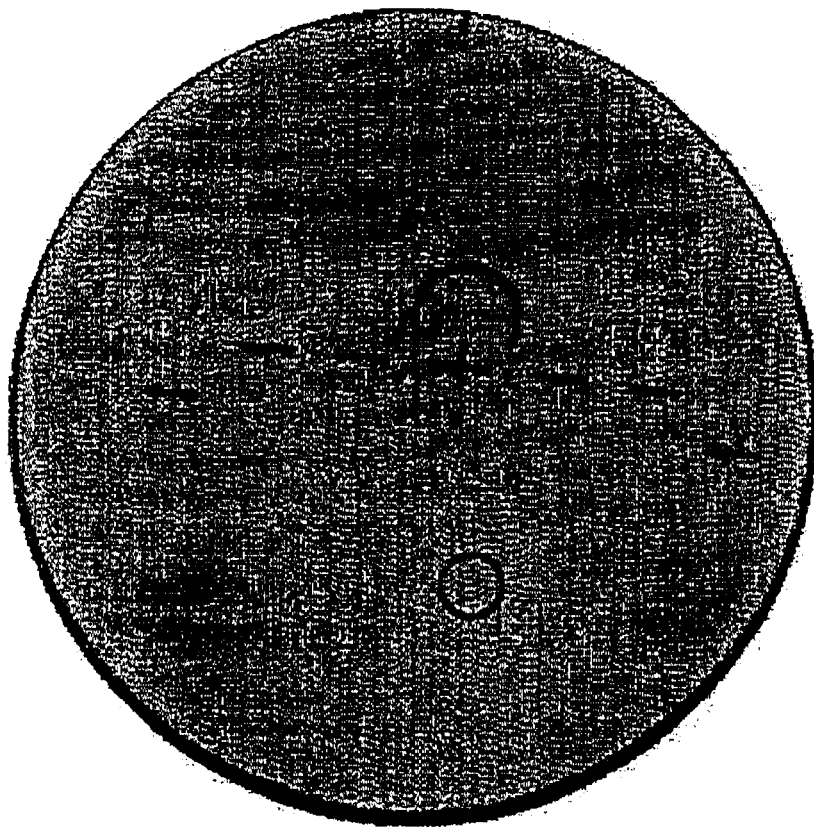


FIG. 4

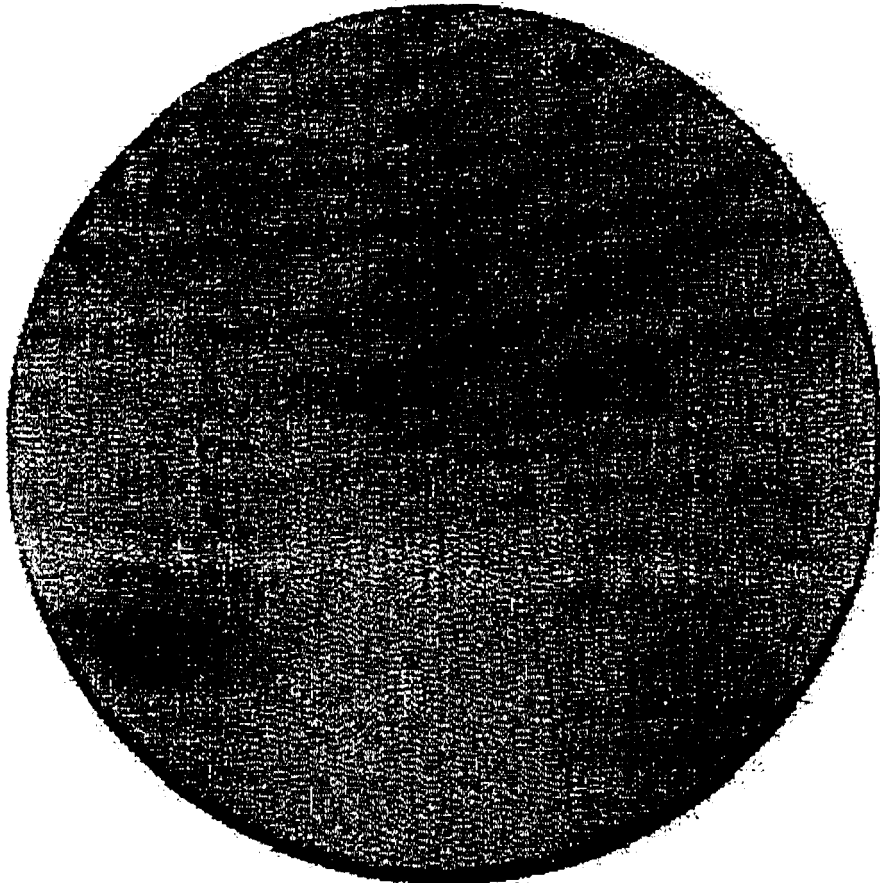


FIG. 5

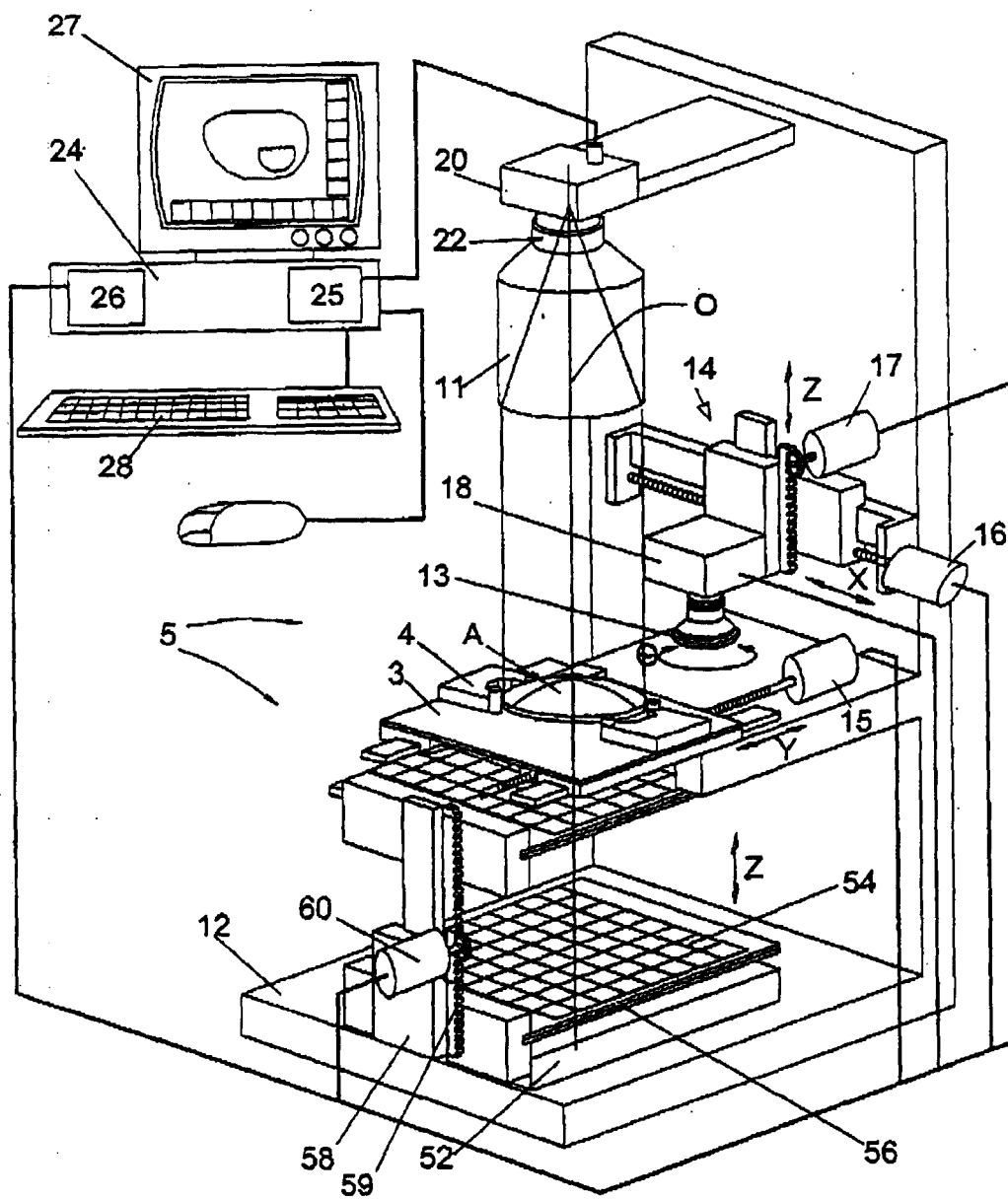


FIG. 6

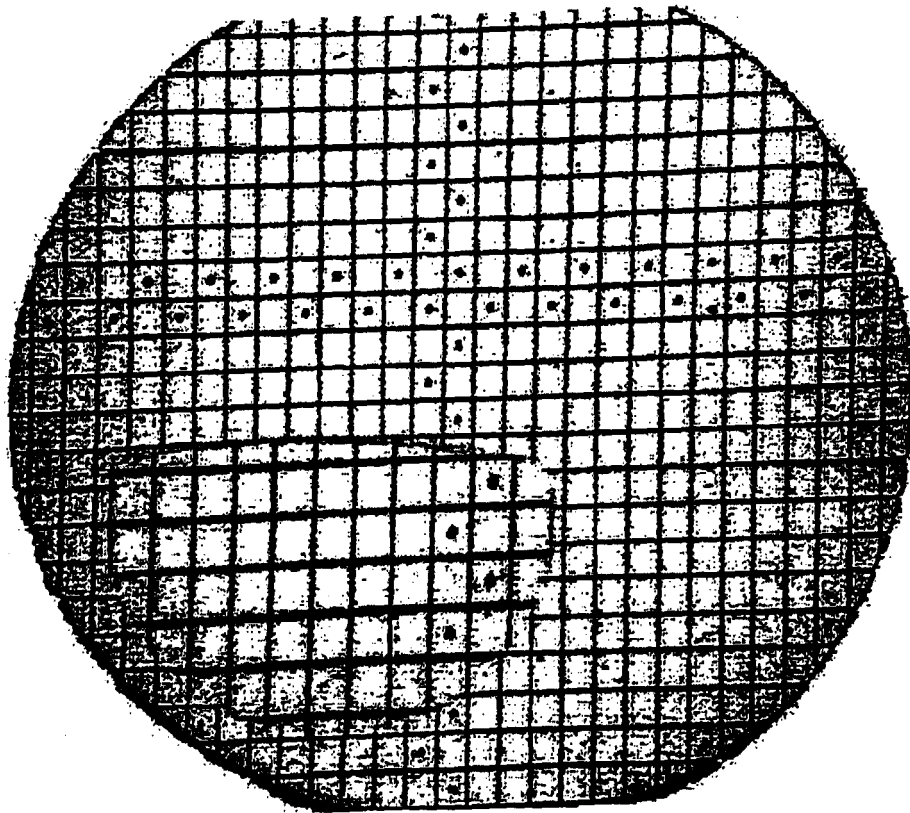


FIG. 7

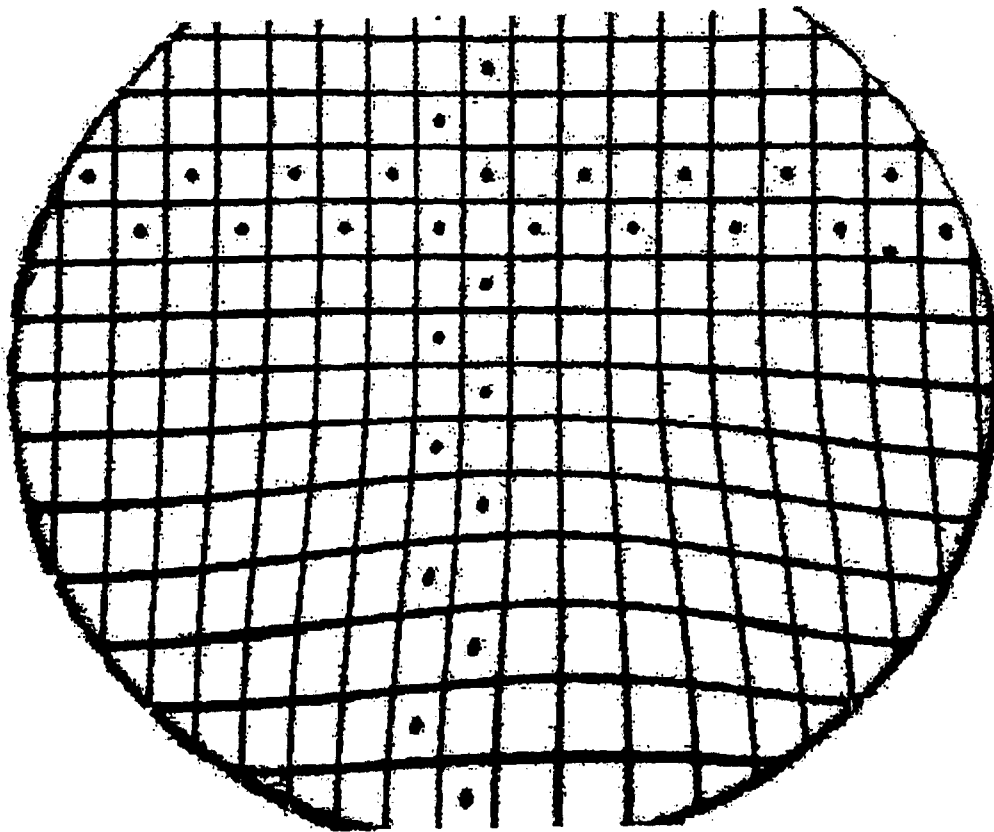


FIG. 8

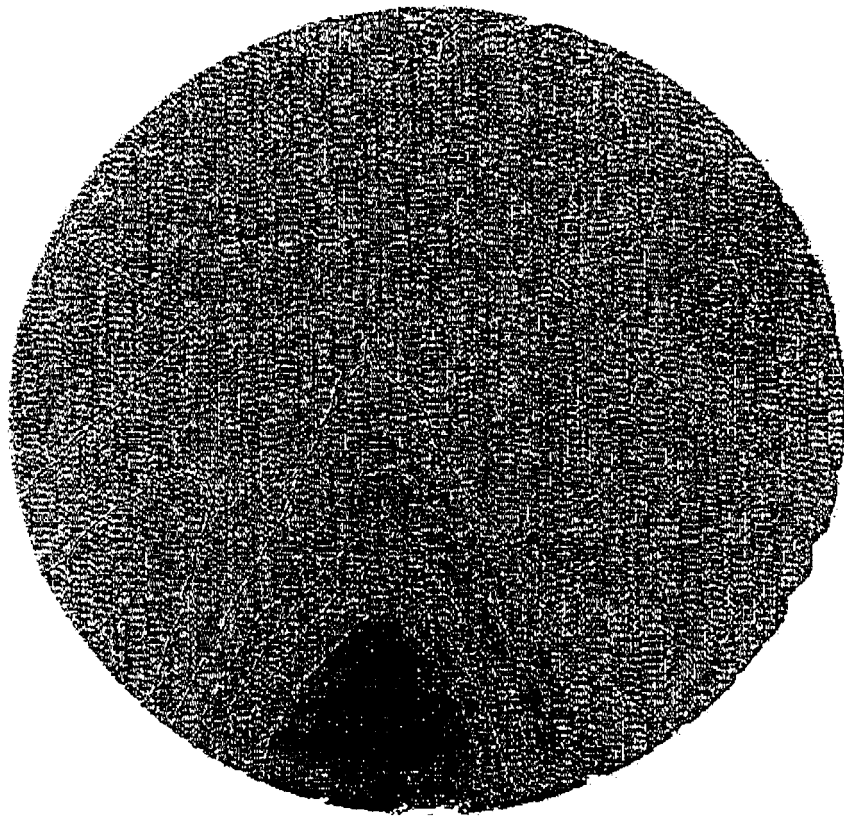


FIG. 9

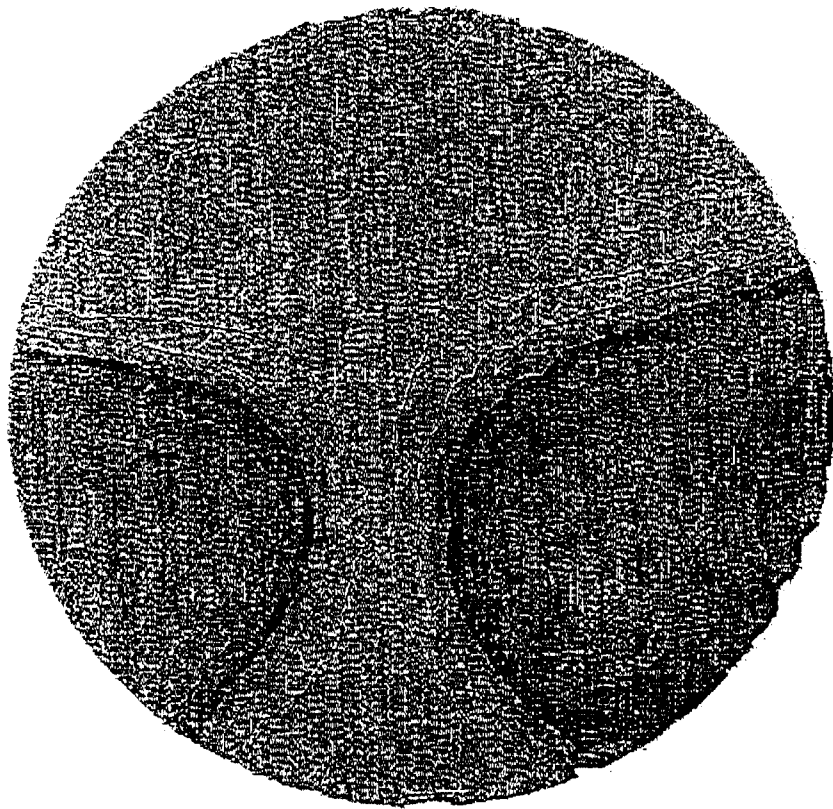


FIG. 10

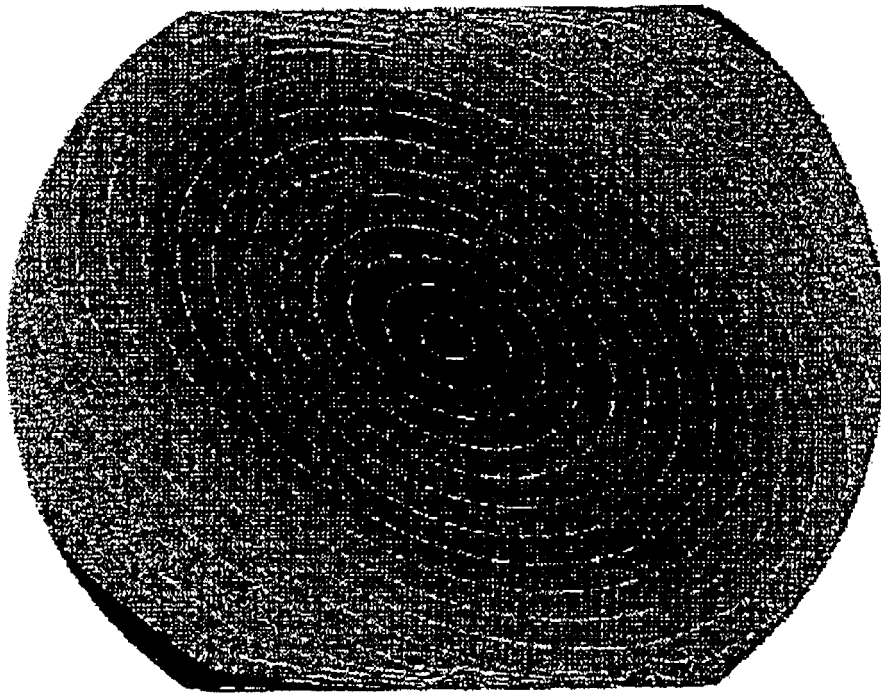


FIG. 11

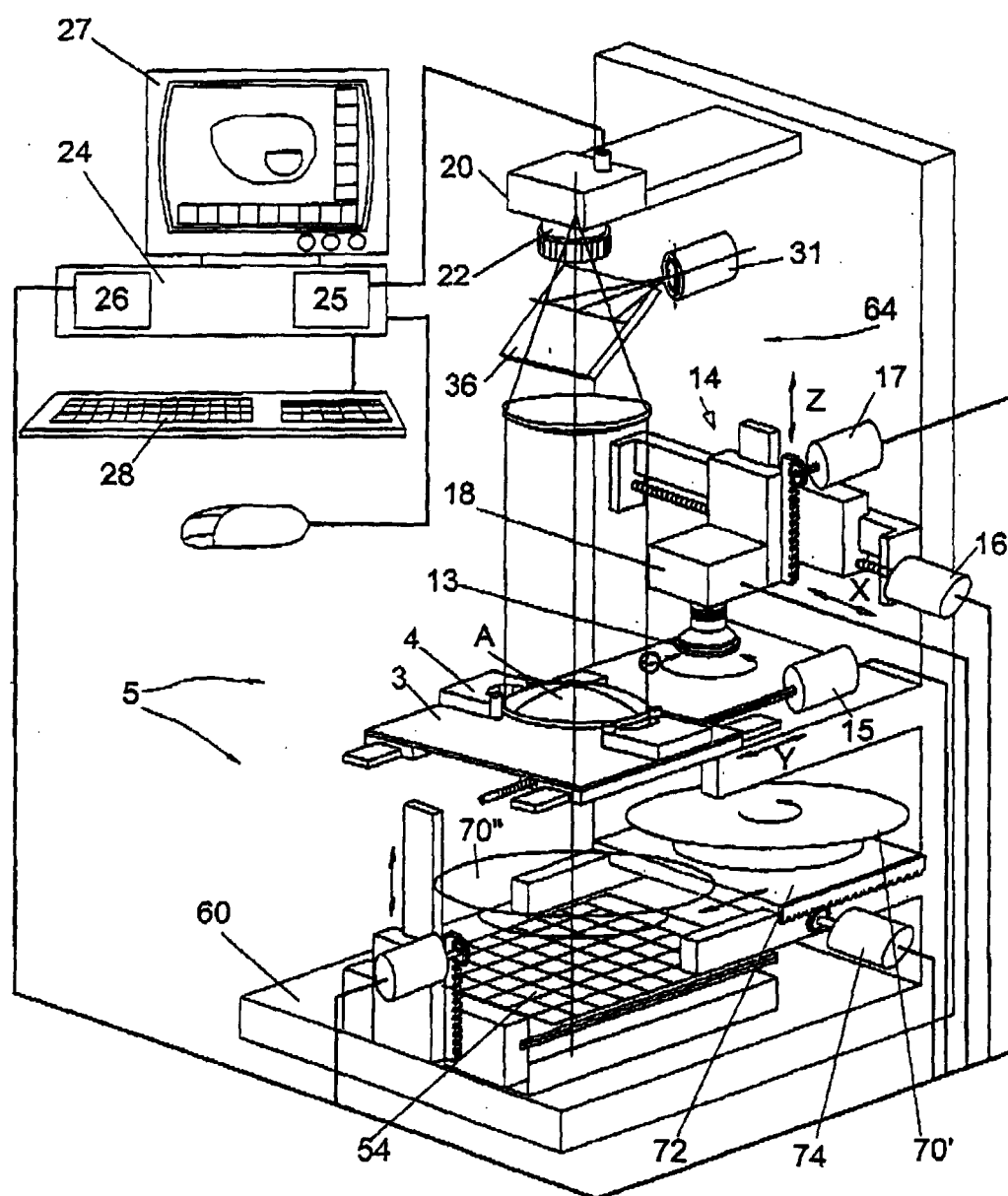


FIG. 12

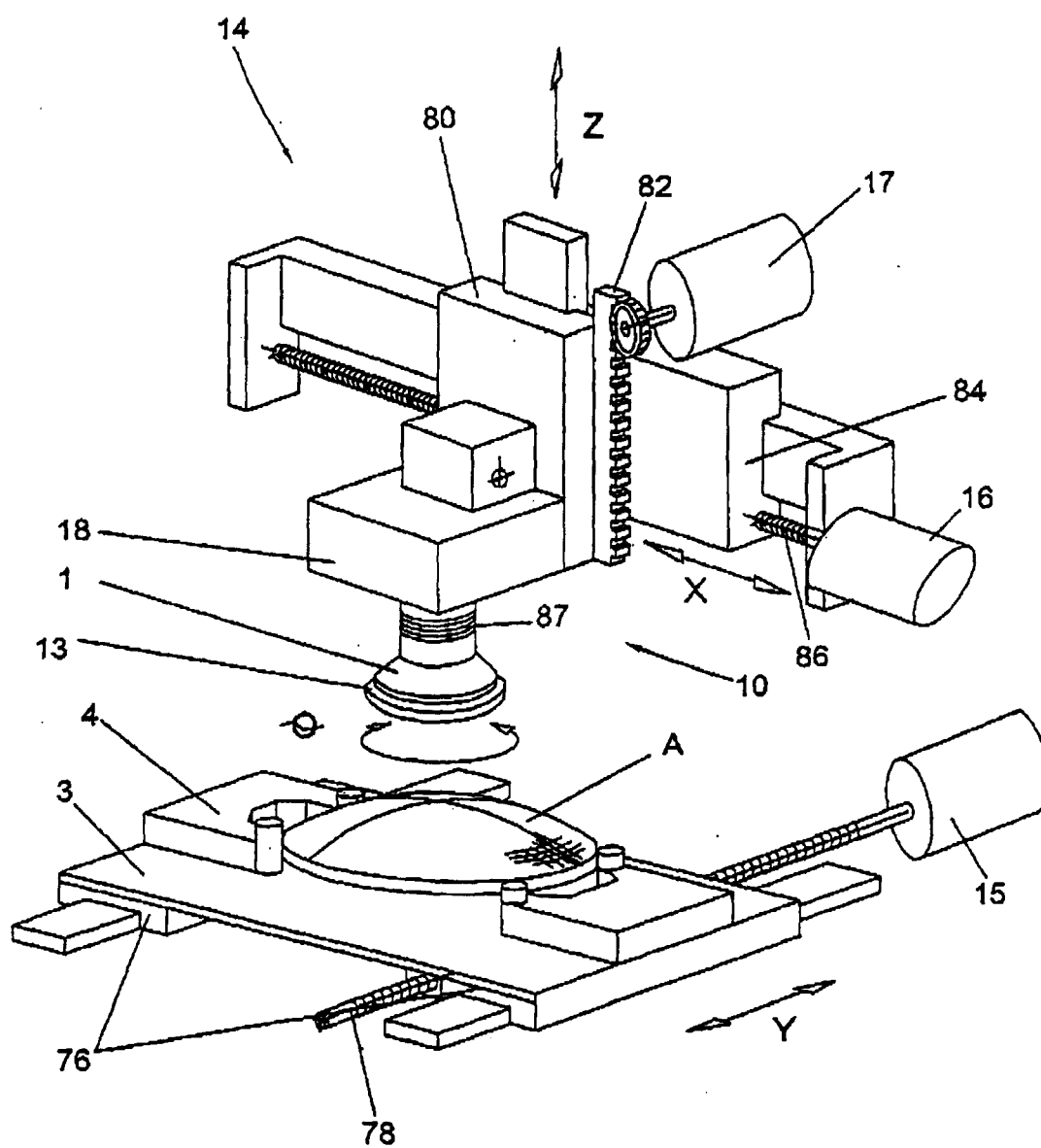


FIG. 13A

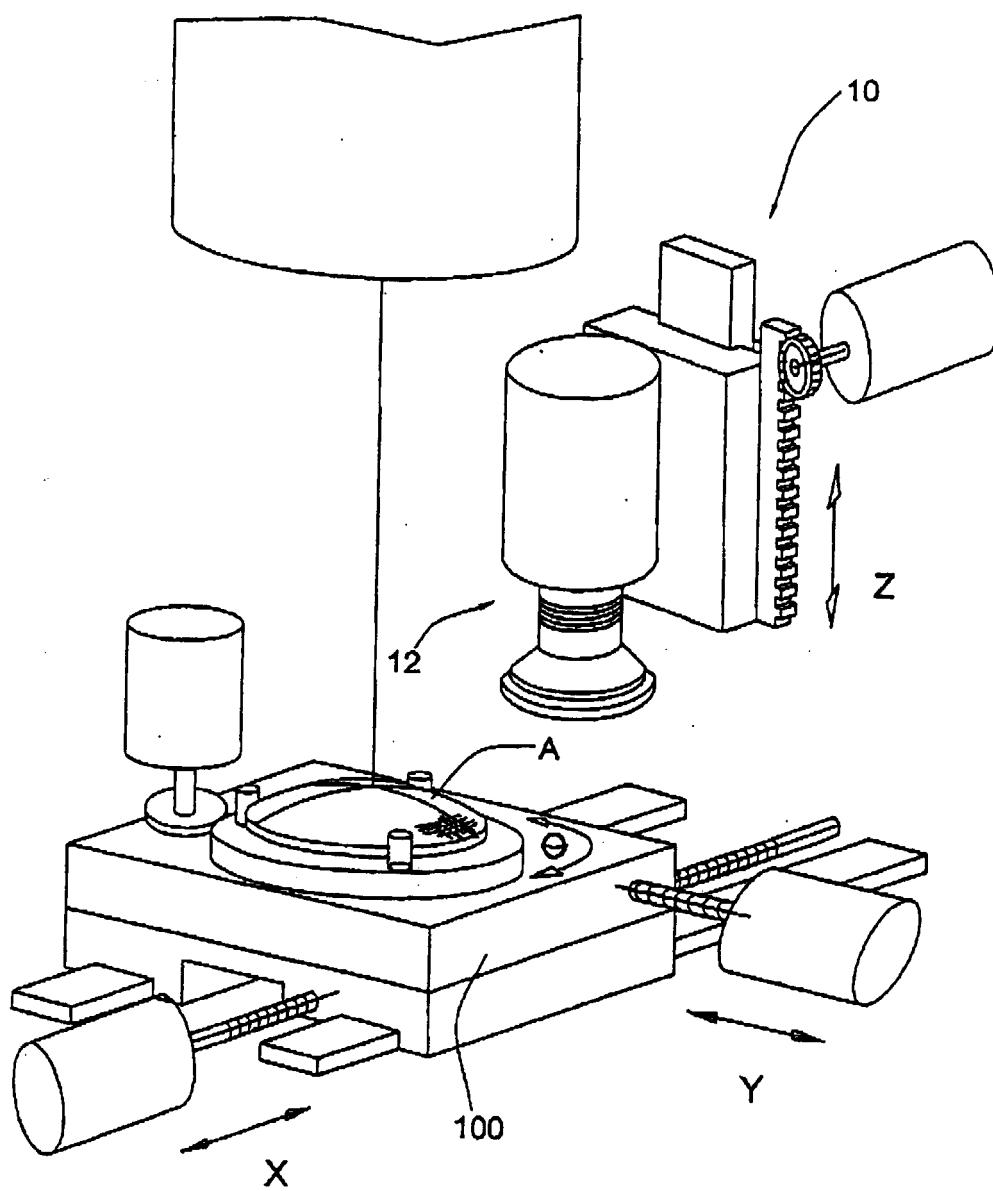


FIG. 13B

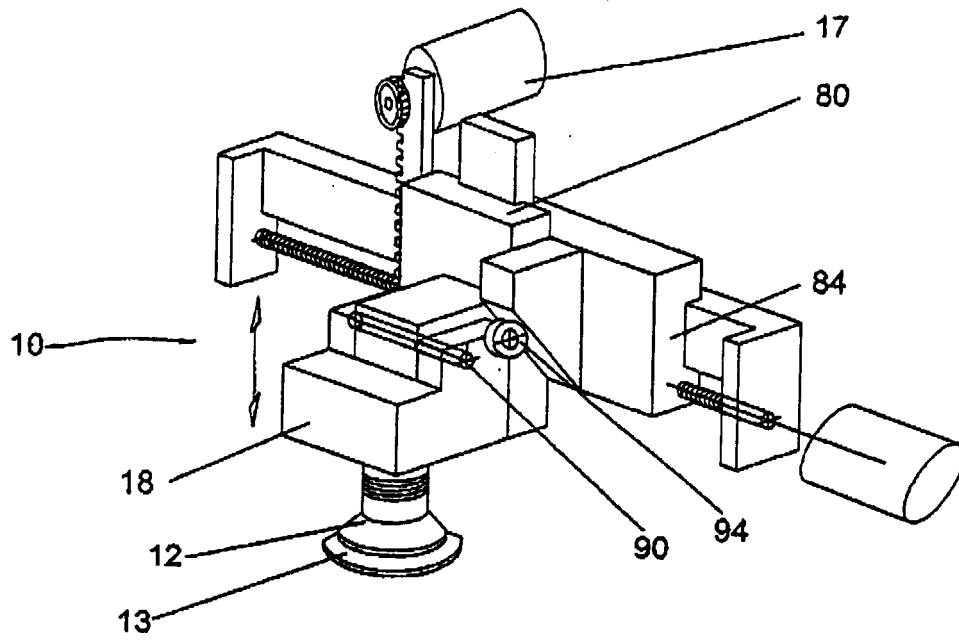


FIG. 14A

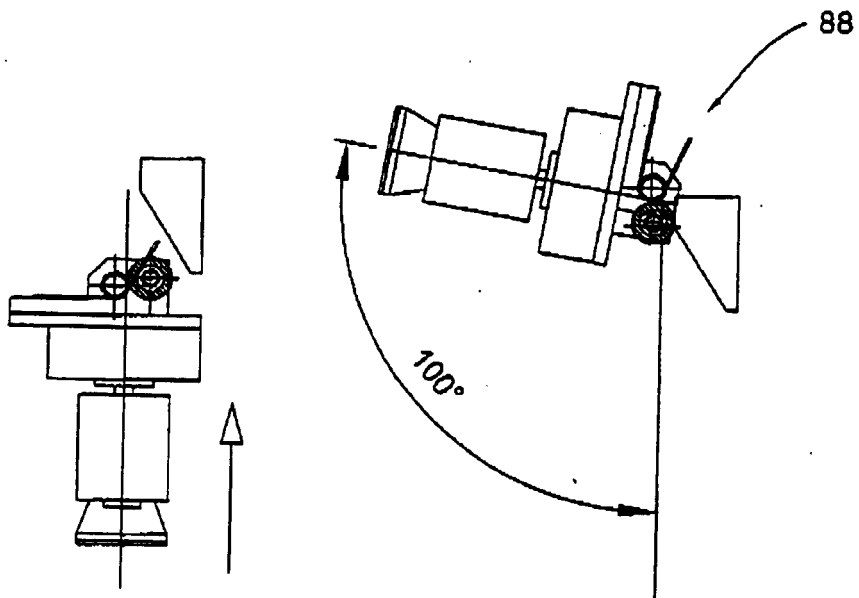


FIG. 14B

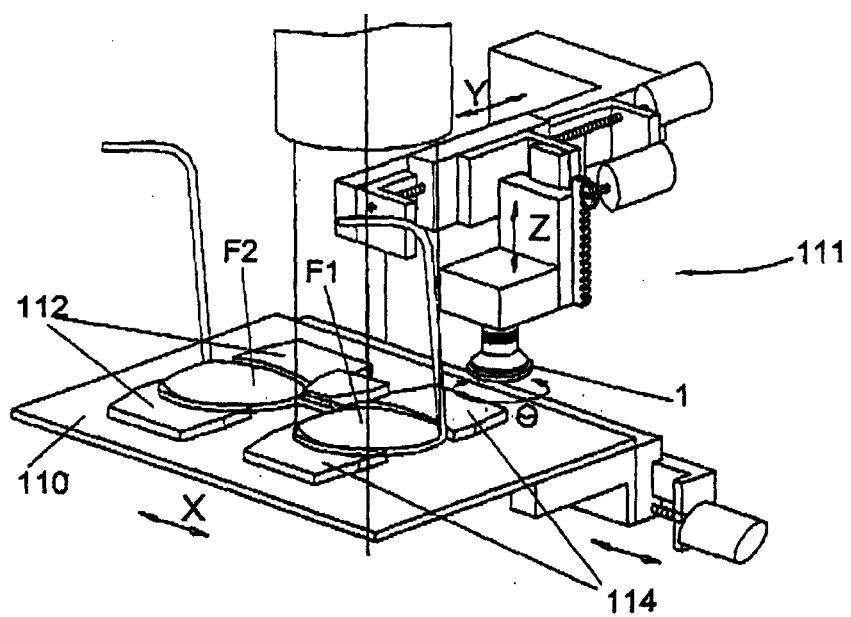


FIG. 15A

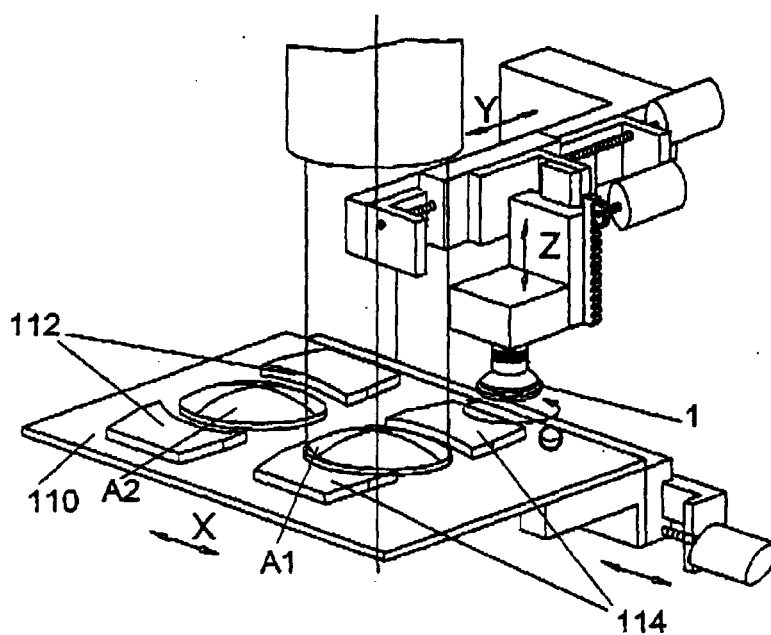


FIG. 15B